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3D computer generated medical holograms using spatial light modulators

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Abstract

The aim of this work is to electronically generate the diffraction patterns of medical images and then trying to optically reconstruct the corresponding holographs to be displayed in space. This method is proposed in a trial to find a smart alternative of the expensive and perishable recording plates.

Keywords: Medical; Hologram; Fourier; Recording; Reconstruction; Image

1. Introduction

Creating holograms of medical images is a recent topic in visualization. Although the idea has been under research more than twenty years ago, no achievement has been done before the last five years. This is because of the very high computer configuration and optical specification required to do the job. Holography is displaying a three-dimensional image of an object in space. The principle is to save an interference pattern of light coming from that object and a reference beam on special recording plates. This pattern includes the information of amplitude and phase differences required to build a 3-D shape. When the holographic plate is later exposed to a laser beam, the three-dimensional hologram could be displayed and observed from different view.

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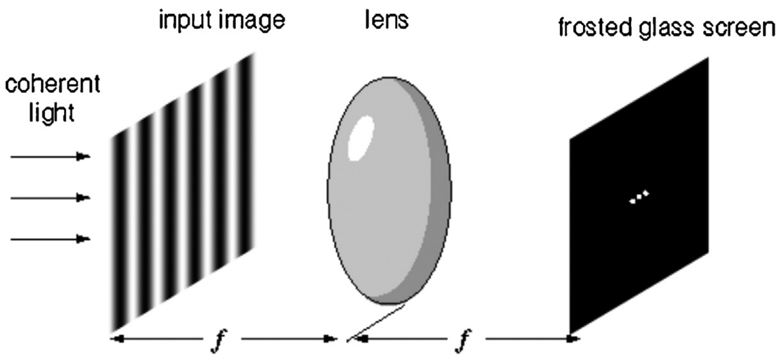

Fig. 1. Optical construction of the Fourier Hologram.

2. Experimental procedures

Creating Computer Generated Hologram (CGH) includes three main steps:

(1) Computation of the virtual scattered wave front (Interference Pattern).
(2) Encoding the wave front data and preparing it for display.
(3) Experimental setup.

The following sections present the explanation of these steps.

2.1. Computation of the virtual scattered wave front

Numerous numbers of methods can be used for computing the interference pattern for a CGH. We used two of them namely the Fourier Transform Holograph and the Gerchbergand Saxton (GS) algorithm

2.1.1. Fourier Transform Holograph

Fourier Transform (FT) Holography refers to the creation of holograms that are the Fourier Transform of the subject. The object and the reference light has to lie in the same plane thus the possible objects to be imaged are restricted to planar apertures. For the diffracted electric field to be approximated by the Fourier Transform of the aperture transmission function $a(x_0, y_0)$, The observation plane, given by $z = z_0$, has to be distant from the object plane. Experimentally, a thin spherical lens introduced between the two planes will perform the Fourier Transform at the focal length f as shown in Fig. 1

The electric field for the aperture centered at $(x_r, y_r, 0)$ is given Eq. (1)

$$E_o \propto e^{ikz} e^{\frac{ik}{2z}(x^2+y^2)} \iint dx_o dy_o a(x_o - x_r, y_{o-} y_r) e^{\frac{-ik}{z}(xx_o - yy_o)}$$
$$= Ce^{ikz} e^{\frac{ik}{2z}(x^2+y^2)} \iint dx_o dy_o a(x_o - x_r, y_{o-} y_r) e^{-i(xx_o - yy_o)} = Ce^{ikz} e^{\frac{ik}{2z}(x^2+y^2)} A(K_x, K_y) \tag{1}$$

The electric field due to the reference point source is given by Eq. (2)

$$E_p(x, y) = e^{ikz} e^{\frac{ik}{2z}(x^2+y^2)} \iint dx_o dy_o \delta \int\int (x_o, y_o) e^{\frac{-ik}{z}(xx_o + yy_o)} C' e^{ikz} e^{\frac{ik}{2z}(x^2+y^2)} \tag{2}$$

The total electric field is the superposition of E_0 and E_p which gives an interference pattern represented by Eq. (3)

$$E(x, y) = E_0(x, y) + E_p(x, y) = C''^{e^{ikz} e^{\frac{ik}{2z}(x^2+y^2)}} [1 + A(K_x + K_y)] \tag{3}$$

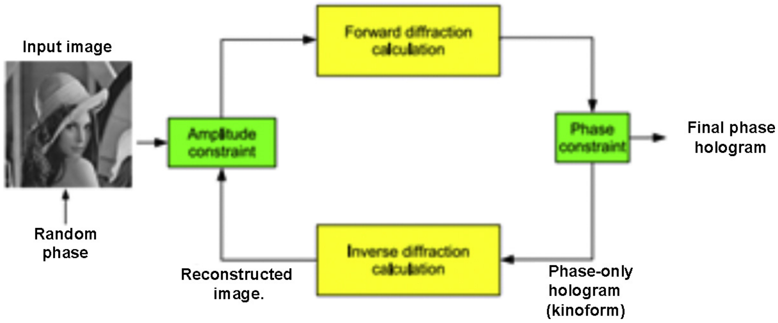

Fig. 2. Typical GS algorithm (Lehar).

2.1.2. Gerchbergand Saxton (GS) algorithm

This is a phase only hologram algorithm used by the SLM software. We employ the GS algorithm as a computational algorithm in order to improve the deterioration of the reconstructed image.

Fig. 2 is a block diagram made by the author to illustrate typical a GS algorithm. In the GS algorithm for Fourier holograms, Fourier and inverse Fourier transforms correspond to reconstructions from a hologram and hologram generation, respectively.

We start the computational algorithm by adding a random phase to an input image, and calculate the diffraction pattern calculation from the latter. We extract only the phase components from the diffracted light to generate a kinoform. The kinoforms are reconstructed by inverse diffraction calculation. We replace the amplitude of the reconstructed light with the original input image. Repeating the above processes, the GS algorithms gradually improve the quality of the reconstructed images.

2.2. Encoding the wave front data and preparing it for display

Once you know what the scattered wave front of the object looks like or how it can be computed, it must be sent to a spatial light modulator (SLM).

SLM is a device that modulates the coherent light spatially based on its control input. The SLM is used to encode output patterns for aerial mapping. Also, the SLM accepts the pattern information from a computer and converts the input coherent light from laser source into the required output patterns.

In our work, we used in our experiments two types of the SLM:

1. PLUTO (Phase Only Spatial Light Modulators)The PLUTO Spatial Light Modulator (SLM) is used to control an LCOS (Liquid Crystal-on-Silicon) active matrix reflective mode phase only LCD with resolution 1920 × 1080 and a 0.7″ diagonal.
2. SLM (LC 2002) Phase and amplitude modulation:SLM (LC 2002) is used to control an LCOS (Liquid Crystal-on-Silicon) active matrix transitive mode with resolution 800 × 600.

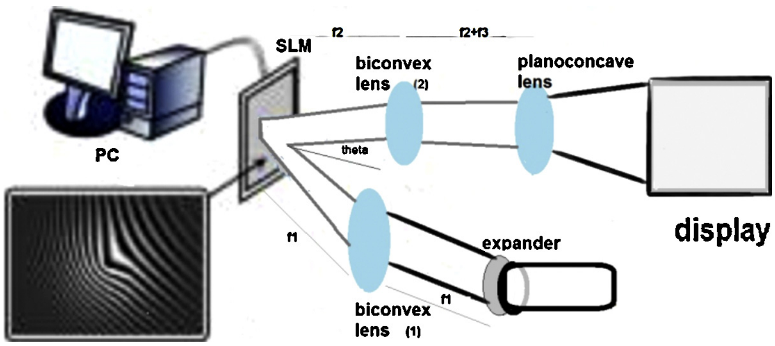

Fig. 3. Reconstruction of the CGH.

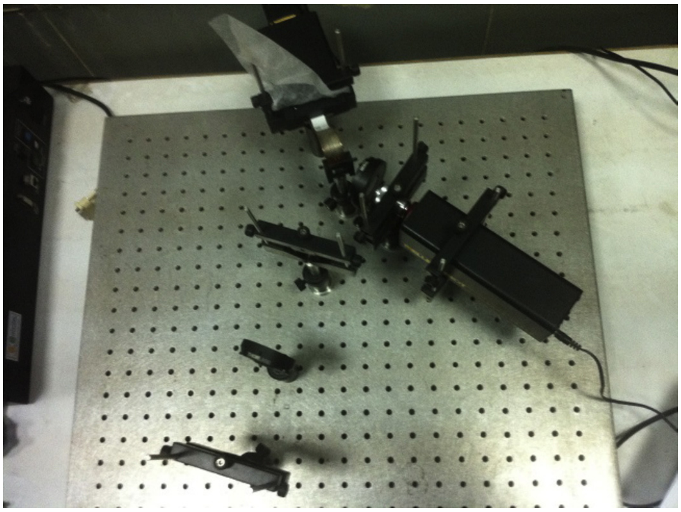

Fig. 4. Top view of the experiment using reflective SLM.

2.3. Experimental setup

Modulating the input interference pattern with coherent light beam by the SLM and some optical elements to observe the hologram on display.

Fig. 3 is a block diagram made by the author to show the elements used to reconstruct the hologram in the experiment which are

- Laser source.
- Beam expander.
- Collimator (Biconvex Lens).
- SLM.
- Biconvex lens (Inverse Fourier).
- Planer concave (magnify the hologram.

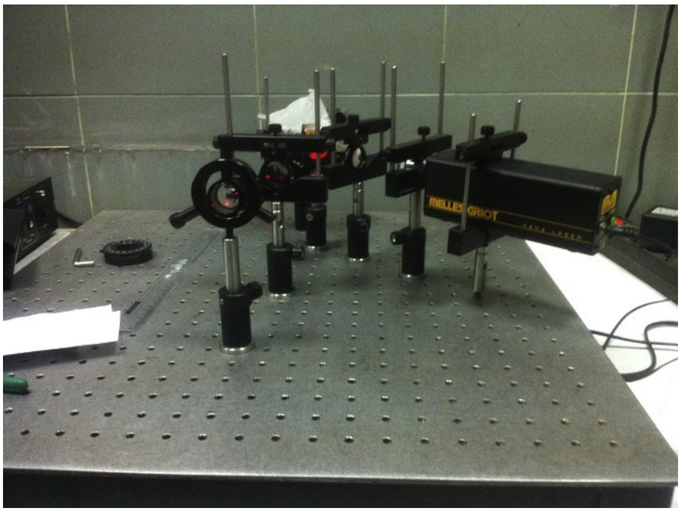

Fig. 5. Front view of the experiment using reflective SLM.

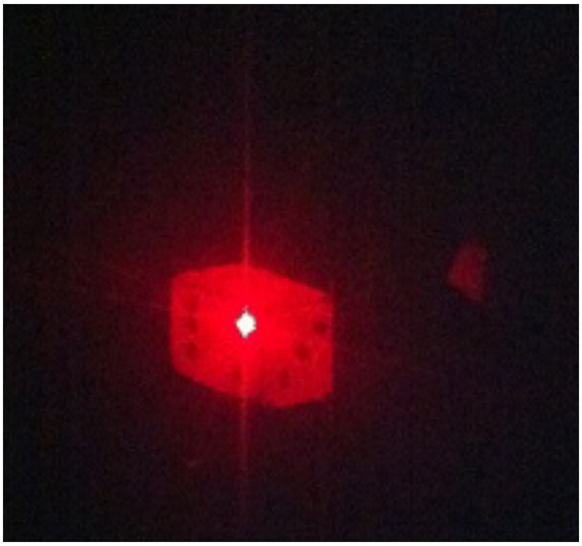

Fig. 6. Result hologram of a dice.

F1 is the focal lens of lens 1 (Collimator).

F2 is the focal lens of lens 2 (Inverse Fourier).

F3 is the focal les of lens 3 (Magnification)

Figs. 4 and 5 show live images of the optical setup used in the experiment taken in the laboratory, front and top shots are taken for the optical table that contains the components of the setup

3. Results

(a) A software program that generates the interference pattern of a 2-D image by Fourier algorithm.
(b) Experiment generates 2-D hologram using PLUTO reflective SLM (as a new trend in reconstructing the holograms) using its software which is built in the GS algorithm.

Figs. 6–8 show images for the output holograms taken in the laboratory.

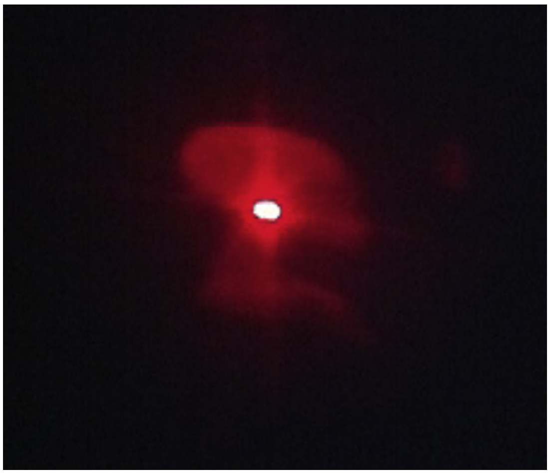

Fig. 7. Result hologram of a skull.

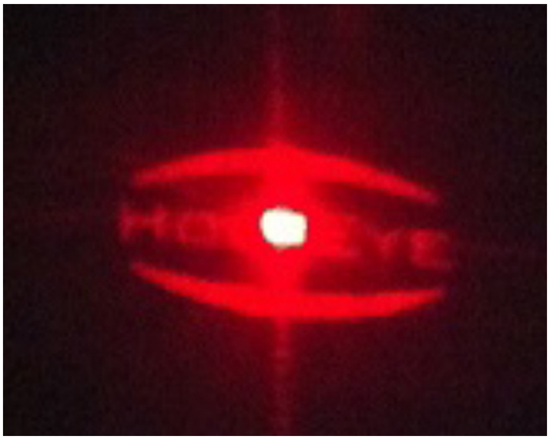

Fig. 8. Result hologram of a HoloEye logo.

4. Future work

We are working on eliminating the DC term that is shown in the resultant image.

We are working on the 3-D hologram and viewing it in space and that can be done using more than one system of this system each one will generate different view of the 3-D object and by specific alignment 3-D hologram can be generated.

5. Conclusions

Combining the Sciences of Optical Engineering, Laser Engineering, Mathematics, Computational Techniques and Software Programming. The author could reach a satisfying output of A three dimensional Holographic Image by the use of SLM And software Algorithm, A result that can be a very good seed for a very interesting research area in the career path of the author.

Reference

http://cns-alumni.bu.edu/~slehar/fourier/fourier.html